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(54) An improved method of making non-woven fabric substrates for carbon fibre reinforced composites

(57) A method is provided of making a non-woven fabric sheet for use as a substrate in a carbon-fibre-reinforced carbon composite. Carded staple fibre is placed transversely to continuous filament and needle punched to form a fabric which is superior to an all-continuous-filament fabric in that (a) it has improved infiltration characteristics and (b) staple fibre recovered from off-cut material can be re-cycled.

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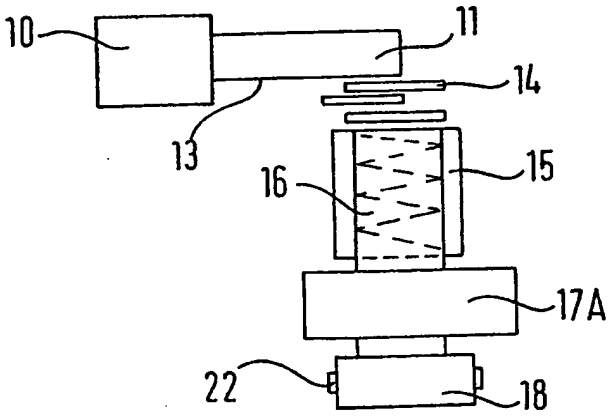


FIG. 1

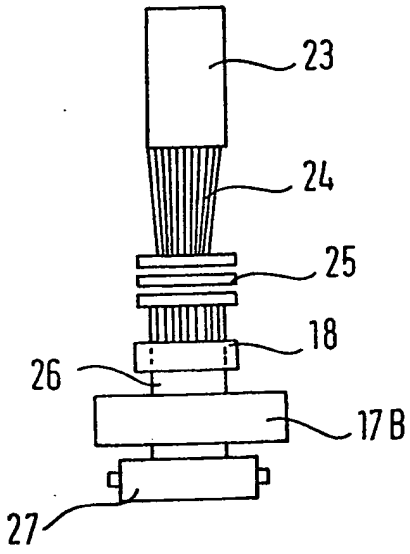


FIG. 2

FIG.3

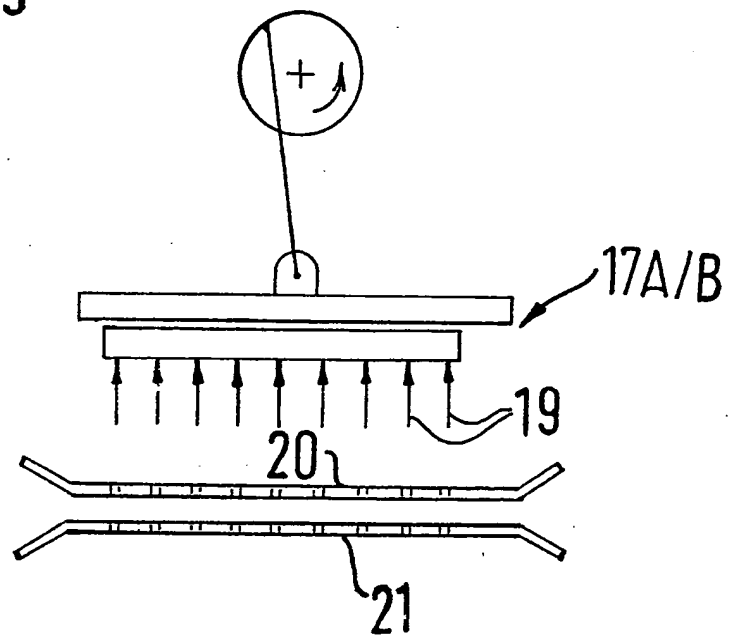
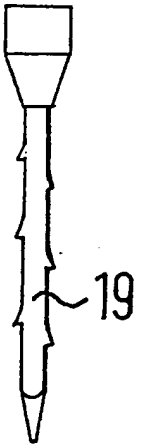


FIG.4



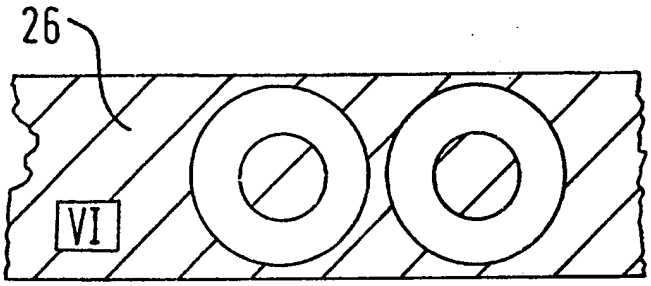


FIG. 5

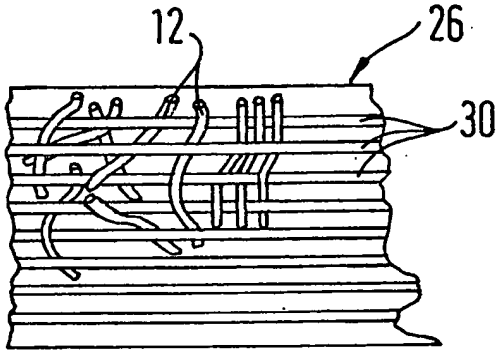


FIG. 6

SPECIFICATION

An improved method of making non-woven fabric substrates for carbon fibre reinforced composites

This invention relates to an improved method of making non-woven fabric substrates for carbon-fibre reinforced carbon composites.

An example of such a composite is an all-carbon brake disc made by depositing a carbon matrix on a fabric substrate the fibrous material of the fabric being carbonised to reinforce the carbon matrix with carbon fibres. The deposition of carbon on the substrate is effected by cracking an organic gas (carbon vapour deposition) or by repeatedly impregnating the substrate with resin and then charring to densify a carbon matrix on the carbonised substrate (multiple impregnation).

A preferred material for the substrate is polyacrylonitrile (PAN) fibre which, especially if the carbon vapour deposition is to be employed, is preferably in an "oxidised" condition which facilitates subsequent carbonisation. This is available as a non-woven fabric or felt comprising crossing layers of continuous filaments, the layers being united e.g. by needle punching.

Taking all carbon brake discs as an example, annuli are cut out of the parallel sided sheet of PAN fibre and then stacked to form a substrate of the desired thickness. This procedure gives rise to considerable wastage of the expensive PAN sheet because the off-cut material cannot be re-processed to continuous filament form to make a new sheet.

It can be re-processed to staple fibre form by chopping the residual filament into relatively short fibres and opening or separating the "warp" and "weft" fibres but there has hitherto been little point in doing this as the primary use of oxidised PAN fibre has been for composite substrates, both the "warp" and "weft" of which have consisted of continuous filament.

According to this invention a fabric of suitable strength and fibre volume characteristics can be obtained using crossing layers one of which is of crimped staple fibre. This yields the substantial advantage that a substrate made from the fabric is more easily infiltrated during a subsequent carbon deposition process. In addition the inclusion of staple fibre in the fabric permits a considerable economy in the use of oxidised PAN fibre because at least a proportion, if not all, of the off-cut material can be re-cycled.

According to the present invention there is provided a method of making from carbonisable fibrous material pre-treated to alter its chemical composition to facilitate subsequent carbonisation a non-woven fabric sheet for use as substrate material in a carbon fibr reinforced carbon composite, th method comprising placing a substantially unidirectional array of continuous filaments transversely to the average direction of carded staple fibres, and consolidating the fibres and filaments to form a fabric sheet by needle punching.

The continuous filaments are preferably held in longitudinal restraint during needle punching.

The pre-treated carbonisable fibrous material used is preferably xidised fibrous polyacrylonitrile.

Preferably a web of parallelised staple fibres from a carding engine is fed to a cross lapper which layers the web to produce a thicker web in which the average direction of the staple fibres is transverse to the web, the thicker web is fed through a needle punch which consolidates it into a felt, the felt and an array of substantially parallel tows of continuous filament are laid so that the average direction of the staple fibres in the felt is transverse to the tows and the felt and tows are united to form a fabric by needle punching with barbed needles.

Felts of staple fibre may be placed on opposite sides of the sheet of filaments so that the latter is sandwiched between staple fibre felts in both of which the average direction of the staple fibres is transverse to the continuous filament and the sheet and the two felts may be united to form a fabric by needle punching with barbed needles.

A substrate of predetermined shape may be cut out of the fabric sheet and off-cut fabric sheet material may be rendered into staple fibre. The off-cut fabric sheet material may be passed in succession through a chopping machine and an opening machine to render it into staple fibre. Staple fibre obtained from the off-cut fabric sheet material may be re-used in the production of further fabric sheet material.

Annuli may be cut out of the sheet and then stacked to form a substrate for an all-carbon brake disc. The stacked annuli may be needle punched to hold them together.

Preferred embodiments of the invention will now be described with reference to the accompanying drawings, in which:–

Figure 1 is a diagram of the lay-out of apparatus for producing a web of staple fibre,

Figure 2 is a diagram of the lay-out of apparatus whereby the web of staple fibres is combined with continuous filament tows to form a fabric sheet,

Figure 3 is a side view of a needle punch suitable for incorporation in the apparatus of Figure 1 and of Figure 2,

Figure 4 is a view on an enlarged scale of one of the needles of the needle punch of Figure 3,

Figure 5 is a view of a sheet produced by the apparatus of Figure 2 after annuli have been stamped or cut out of it, and

Figure 6 is a greatly enlarged view of the area "VI" of the sheet of Figure 5, showing the orientation of the continuous filaments and staple fibres which constitute the sheet.

In a preferred embodiment of the invention PAN fibre is used at the "oxidised" stage when it is sufficiently pliable to be subject d to textile processes. Oxidised PAN c ntinuous filament treated t between 220°–300°C is pr cessed into crimped staple fibr by apparatus well known in the t xtile art. It is preferably converted into "top" by stretch-breaking, crimping, tow-to-top converting and Willeying. The staple is fed through a carding engine 10 to produce a thin, light web 11 of "parallelised" fibres, i.e. the average direction of the majority of

the fibres 12 (Figure 6) is parallel to the offtake belt 13 of the carding engine. The web is fed from the belt 13 to a cross lapper 14 which lays the thin web 11 backwards and forwards n a belt 15 moving at right angles to the belt 13 to produce a thick, bulky web 16 in which the average direction of the parallelised staple fibres is at right angles to the belt.

The belt 15 feeds the thick web 16 through a needle punch 17A which consolidates it into a felt 18 by the action of its barbed needles 19 (Figures 3 and 4) which reciprocate through the felt as it passes between perforated top and bottom guide plates 20 and 21. The consolidated felt 18 is then wound onto a take up roll 22.

The "warp" for the fabric is made from a number of oxidized PAN continuous filament tows let off from a creel, beam, plated box, coil cans or other suitable package 23 (Figure 2). Each tow may be of the 10,000 filament type, or heavy-weight tows of approximately 320,000 filaments may be used. The tows are brought together to form a sheet 24 by passing through suitable guides, tension control and tow-spreading devices 25. A portion of suitable length of the previously made "weft" felt 18 is laid on the sheet 24 and they are fed together through a second needle punch 17B, which may resemble that shown in Figures 3 and 4, to produce a consolidated non-woven fabric sheet 26 which may be wound onto a take up roll 27.

Optionally the sheet 26 may comprise more than one "warp" layer or more than one "weft" layer, and in a preferred such multi-layer construction the "warp" sheet 24 is sandwiched between two "weft" felts 18 laid above and below it, the whole being needle punched together.

A substrate for a brake disc is made by cutting similar annuli out of the sheet 26 and stacking them to the desired thickness with the fibres of adjacent annuli in a chosen angular orientation. The stack of annuli is preferably needle punched both to facilitate handling and to help to avoid delamination of the finished product. The whole substrate is then heat treated to in excess of 1000°C in the absence of oxygen to complete the carbonisation of the fibre. The disc is then converted into carbon/carbon composite by either the carbon vapour deposition or resin char route. Because there is no twist in the fibre and the voids within the fabric are more uniform than in the case of cloths produced from yarns there is a reduction in the time that it takes to infiltrate the substrate. This reduction may be 60% or more.

Figure 5 illustrates the off-cut material of the fabric sheet 26 which remains when the annuli have been cut out, and Figure 6 shows that this is constructed from parallel continuous filaments 30 extending longitudinally of th sheet 26, and staple fibres 12 which, through being "parallelised" by the carding ngin 10, have an average direction which is transvers to the c ntinuous filaments 30 but which are t some xtent random orientated and hav become intermixed with th c ntinuous filaments 30 through the action f the needle punches 17A and 17B.

In accordance with the present invention the off-cut material f the sheet 26 can be passed in succession through a chopping machine, which reduces the length of the c ntinuous filaments 30 roughly to that of the staple fibres, and an opening machine which separates the crossing fibres. The resulting staple fibre can be blended in a suitable proportion (up to 50% or more) with virgin PAN staple fibre and the blend fed to the carding engine 10 for the production of more "weft" web 18 as previously described.

Excess offcuts which are of reduced quality can still be opened and blended. The resultant fibre can then be carded and needled to produce carbon felt to be used for less exacting tasks than brake discs e.g. thermal insulation, or for processing into carbon composites which would be used in products to compete with high grade graphites.

CLAIMS

1. A method of making from carbonisable fibrous material pre-treated to alter its chemical composition to facilitate subsequent carbonisation a non-woven fabric sheet for use as substrate material in a carbon-fibre reinforced carbon composite, the method comprising placing a substantially unidirectional array of continuous filaments transversely to the average direction of carded staple fibres and consolidating the fibres and filaments to form a fabric sheet by needle punching.

2. A method as claimed in claim 1 wherein the continuous filaments are held in longitudinal restraint during needle punching.

3. A method as claimed in either preceding claim, wherein the pre-treated carbonisable fibrous material used is oxidised fibrous polyacrylonitrile.

4. A method as claimed in any one of the preceding claims, wherein a web of parallelised staple fibres from a carding engine is fed to a cross lapper which layers the web to produce a thicker web in which the average direction of the staple fibres is transverse to the web, the thicker web is fed through a needle punch which consolidates it into a felt, the felt and an array of substantially parallel tows of continuous filament are laid so that the average direction of the staple fibres in the felt is transverse to the tows and the felt and tows are united to form a fabric by needle punching with barbed needles.

5. A method as claimed in claim 4, wherein felts of staple fibre are placed on opposite sides of the sheet of filaments so that the latter is sandwiched between staple fibre felts in both of which the average direction of the staple fibres is transverse to the continuous filaments and the sheet and the two felts are united to form a fabric by needle punching with barbed needles.

6. A meth d as claimed in any one of the preceding claims, wh rein a substrat of predetermined shap is cut ut f the fabric sheet and offcut fabric sh et material is rendered into stapl fibre.

7. A method as claimed in claim 6, wh rein staple fibre obtained from the off-cut fabric sheet material is re-used in the production of further fab-

ric sheet material.

8. A method as claimed in claim 6 or claim 7 wherein the off-cut fabric sheet is passed in succession through a chopping machine and an opening machine to render it into staple fibre.

9. A method as claimed in any one of claims 6 to 8 wherein annuli are cut out of the sheet and then stacked to form a substrate for an all-carbon brake disc.

10. A method as claimed in claim 9 wherein the stacked annuli are needle-punched to hold them together.

11. A method of producing from carbonisable fibrous material pre-treated to facilitate subsequent carbonisation a non-woven fabric sheet for use as substrate material in a carbon fibre-reinforced carbon composite substantially as described herein with reference to the accompanying drawings.

12. A non-woven fabric sheet produced by the method claimed in any preceding claim.

13. A substrate made by stacking pieces cut from the sheet claimed in claim 12 and needle-punching the stack.

14. A carbon-fibre-reinforced carbon composite comprising a substrate made from the fabric sheet material claimed in claim 12 or as claimed in claim 13.

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